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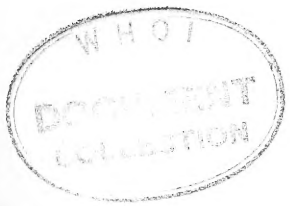

SEA NOISE VS NEAR AND DISTANT WAVE HEIGHT AND WIND SPEED

Correlation of measurements made in deep, open-ocean areas of the Northeast Pacific

W. L. Frisch • Research and Development Report • 11 July 1966

U. S. NAVY ELECTRONICS LABORATORY, SAN DIEGO, CALIFORNIA

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PROBLEM

Within a general investigation of the properties, mechanisms, and origins of low-frequency underwater ambient noise, examine the relationships, if any, between deep, open-ocean ambient sea noise, in the frequency range from 10 to 400 c/s, and both near and distant wave height and wind speed.

RESULTS

1. Sound pressure spectrum level is influenced by wave height and wind speed at both ends of the frequency range from 10 to 400 c/s; greatest dependence is in the 160-to-400-c/s portion.

2. Ambient-noise levels in the range from 32 to 160 c/s are the least influenced by near and distant wave height.

3. No dependence of ambient-noise levels on distant wave-height fluctuation was observed for periods during which local wave-height conditions were moderate and uniform.

RECOMMENDATIONS

1. Extend the analysis of the noise data acquired in this project to ambient noise below 10 c/s.

ADMINISTRATIVE INFORMATION

Work was performed under SF 101 03 15, Task 8119 (NEL L20461). The report covers work from 1 July 1965 to 1 June 1966 and was approved for publication 11 July 1966.

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INTRODUCTION

The classic curves of Knudsen[1] (fig. 1) and Wenz[2] (fig. 2) show the relationship between ambient noise in the ocean and storm or wind activity in terms of wind speed or wave height measured directly, or very nearly directly, above the area in which the sound measurements are made. The Knudsen curves, which treat the frequency range from about 100 c/s to 10 kc/s, describe a consistent dependence of noise level on wind speed and wave height. The Wenz curves treat frequencies down to 1 c/s, and reflect the lack of such dependence below 100 c/s in much of the experimental data.

It is not well known what relationships, if any, exist between ambient-noise levels in the very-low frequencies and storm activity occurring at great distances from the hydrophone. The hydrophones that provided data utilized for this report were located in deep ocean areas providing conditions favorable for the reception of any low-frequency noise propagated from distant storm centers.

In a pilot study[3] ambient-noise levels were considered to be related to the action of winds at the interface. Wind fields over increasing areas to as far as 1400 nautical miles from the hydrophone were considered.

In general, the trends suggested a dependence of ambient noise on wind speed in both the high and low ends of the frequency range considered. The dependence decreases with range, but the decrease is smaller at frequencies below 25 c/s. Anomalous results were noted at 20 c/s.

This study examines the dependence of ambient noise in the frequency range of 10 to 400 c/s on wave height. Wave height is measured both in very near proximity to the hydrophone and at great distances. In addition, changes in noise level are compared with changes in wind speed measured in moderate proximity to the hydrophone.

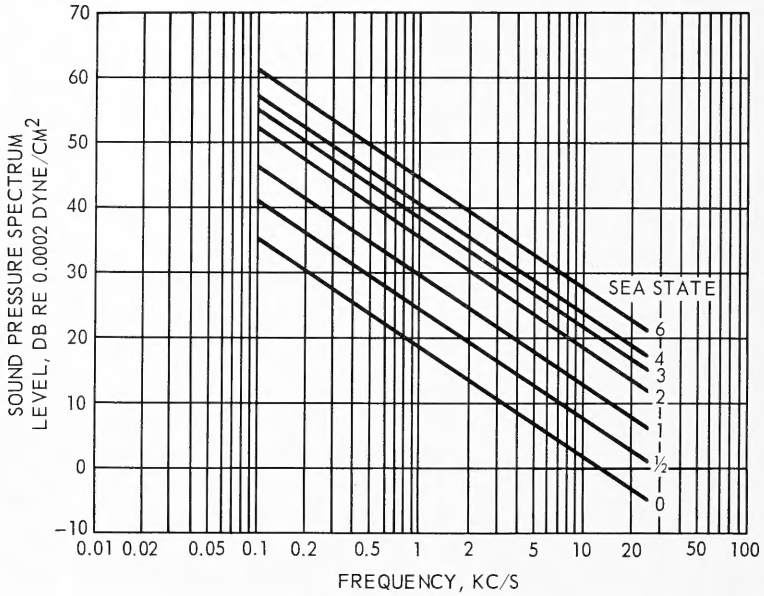


Figure 1. Sea-noise spectra for various sea states.

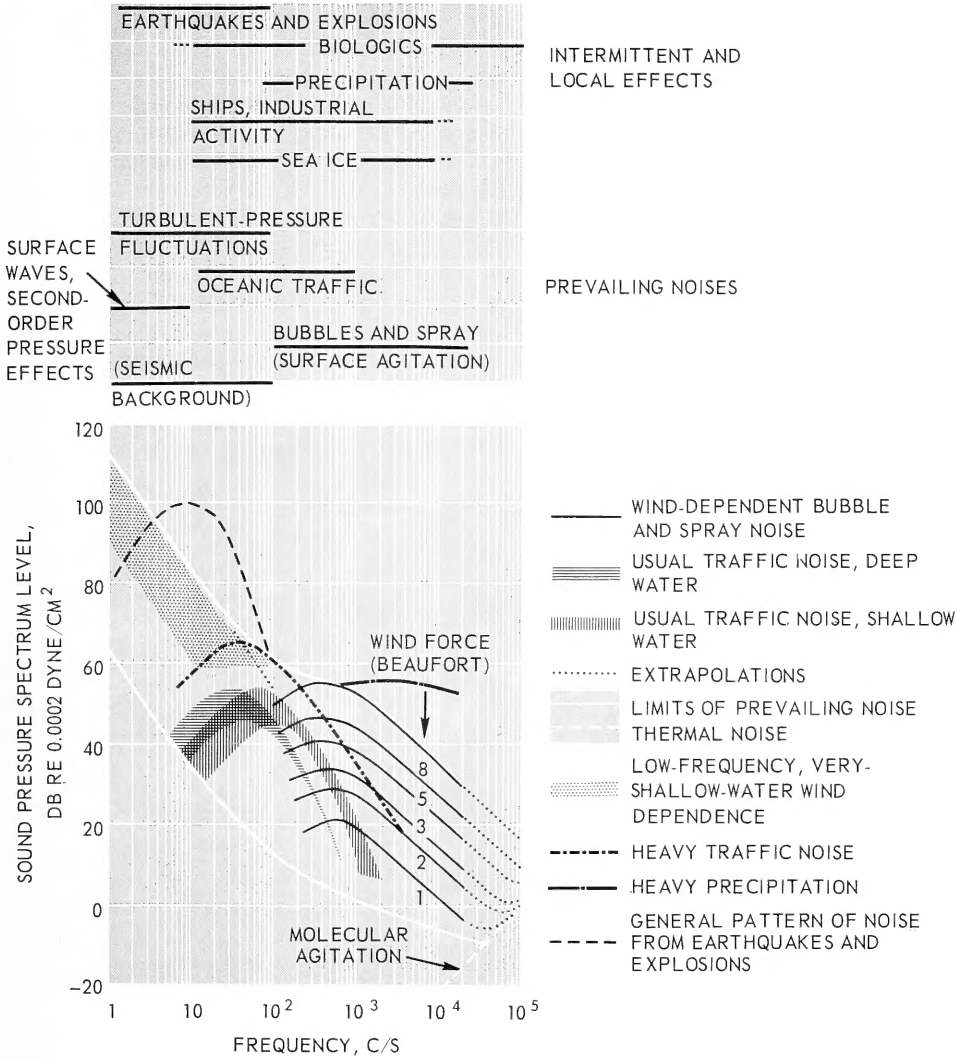


Figure 2. Ambient-noise spectra, summarizing results and conclusions concerning spectrum shape and level and probable sources and mechanisms of the ambient noise in various parts of the spectrum between 1 c/s and 100 kc/s.

METHODS

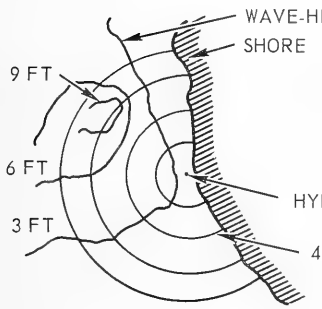
The noise data originated from four hydrophones located at depths greater than 500 fathoms. The four hydrophone stations were selected to sample the Pacific coastal area from Washington to Southern California. They are designated A, B, C, and D in order from north to south. The larger part of the analysis was done on station A, which provided ambient-noise data with a nominal amount of contamination by ship and general transients, and had larger fluctuation in wave height at large distances from the hydrophone.

Data on wave height[4,5] were supplied by the Fleet Numerical Weather Facility, U. S. Naval Postgraduate School, Monterey, California, in the form of contour charts of wave height in 3-foot intervals for the general areas of interest (fig. 3).

Figure 3. Portion of wind-wave analysis for 0600 GMT 01 October 1964 from Fleet Numerical Weather Facility, Monterey, California, showing wave-height contours. Contour interval is 3 feet.

One problem encountered in treating the noise data was contamination by ship and traffic noise. Traffic noise, the contribution of distant ships, is frequently not recognizable in the noise records. Ship noise, however, displays a pronounced transient effect on a continuous display in both broadband records and third-octave-band records, particularly in the 50-to-63-c/s region. For times during which there were obvious transient effects in the broadband records, all noise data were deleted from the data from station C, which were heavily contaminated. Figure 4 shows some of the characteristic transients of these broadband records. In this example, all of record C and all the third-octave-band data corresponding to the times designated by arrows on records A and B were deleted.

The method of recording sea-state conditions was to take the hydrophone location as the center for the generation of a series of ranges at equal radial increments as depicted:



RANGE, N. M.		200	400	600	800
MAX WAVE HEIGHT, FT	2	3	5	9	8

In most instances, the storm configurations were such that it was convenient and practical, as a first approximation, to use linear interpolation. Data were recorded according to wave height in the immediate vicinity of the hydrophone and the maximum values of wave height observed anywhere on arcs at radial ranges of 200, 400, 600, and 800 nautical miles from the hydrophone.

These data were compared with ambient-noise levels recorded at the center of the system, which were reduced by the third-octave digital analyzer [6,7] to third-octave-band data starting at 10 c/s and ending at 400-c/s midband frequency. Coefficients of correlation between the third-octave-band noise levels and the

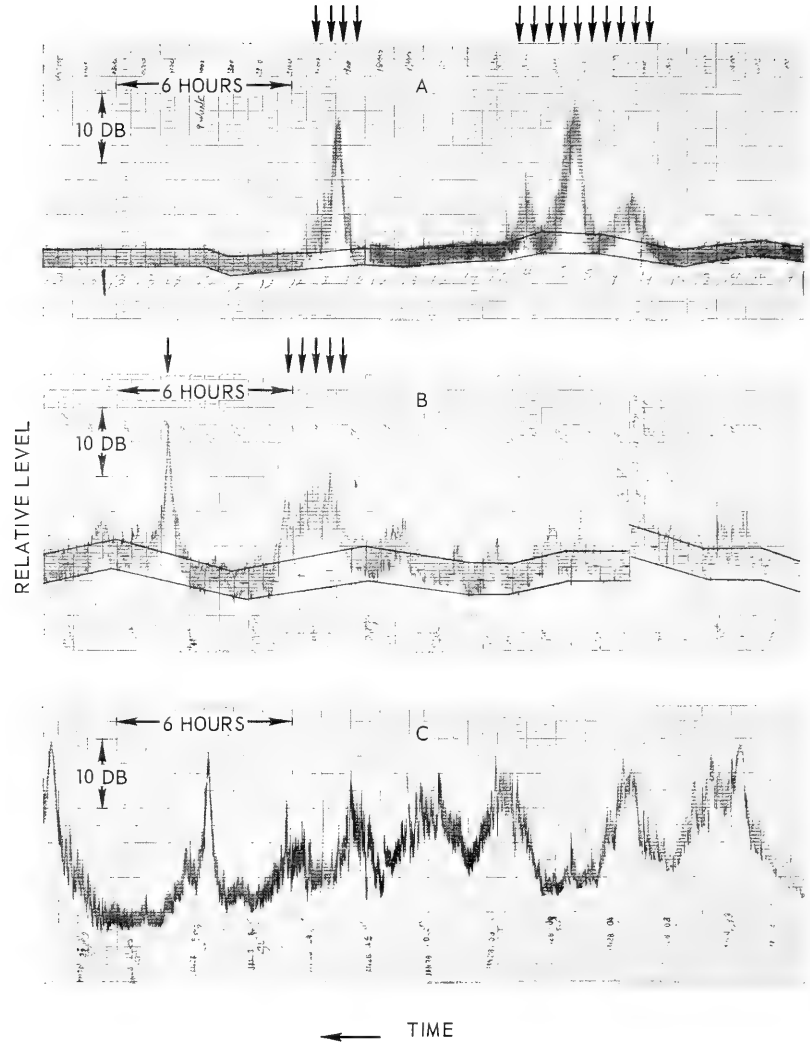


Figure 4. Typical sections of records of broadband ambient-noise levels.

cumulative wave heights* at increasing areas surrounding the hydrophone, were computed. General trends in dependence of noise levels for particular frequencies on varying areas of storm magnitude may be detected in this way.

One of the salient problems associated with the study is the possible overlap of the effect of storm activity at the various ranges. For this reason, an effort was made to study the effect of distant changes in wave height corresponding to times when wave height nearby was relatively constant and small. The most frequently occurring waves above the hydrophone were less than 3 feet, and one grouping was designed to observe only the times for which the area had this sea state. Subsequent examination showed that the most frequently occurring sea state at 200 nautical miles was 3 feet. A second sort, made to include only times for which the sea state was constant over the hydrophone (less than 3 feet) and at the 200-nautical-mile range (3 feet), enabled better judgment from the correlation coefficients of the effect of distant wave fluctuation on ambient-noise level.

A property of the maximum wave heights recorded from the contour charts further compounded the aforementioned problems. The validity of the correlation tests is subject to further question as a few of the wave-height distributions were not normal. Note in figure 5 the extremely skewed curves for the wave heights at the source and at the 200-nautical-mile range. With further increases in distance from the shoreline the distributions begin to take on a more normal form.

The correlation between ambient sea noise in the low-frequency range and local storm activity was further explored with data from an automatic weather buoy associated with CNO Project DS/200. The data were compared with third-octave-band ambient-noise data at station D by means of the correlation coefficient and by grouping the noise data to correspond to sets of wind data that fell within certain Beaufort groupings.

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* Simple sums — the value at the source plus the maximum value at 200 nautical miles, the preceding plus the maximum value at 400 nautical miles, and so on.

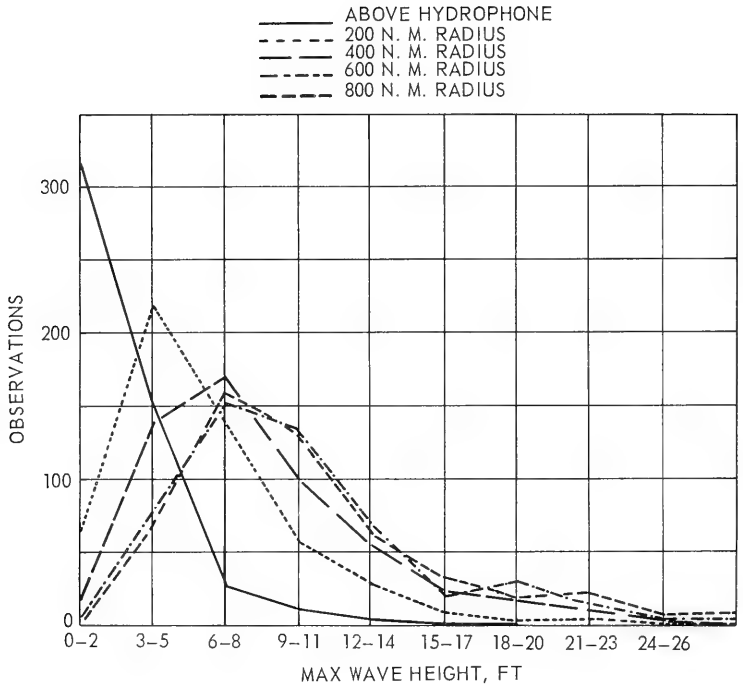

Figure 5. Distribution of maximum wave heights.

RESULTS

The effect of ever-increasing areas (approximated by the cumulative wave-height tabulations) over which maximum wave height is considered on the ambient-noise level in the third-octave-band channels at each station is shown in figure 6. With the exception of station C, all stations yielded coefficients of correlation* which suggest a noise/wave dependence at frequencies less than about 32 c/s and greater than about 160 c/s.

An apparent anomaly in the neighborhood of 20 c/s is noted in figure 6. A possible explanation for it is the way the respective seasonal characteristics of sound pressure level in these frequencies vary with the seasonal wave-height characteristics. Note in figure 7 that all stations exhibit a significant increase in sound pressure level in the 20-c/s band for the months of September and October. The increase probably results from 20-c/s signals previously reported by Cummings and Thompson[8]. In the areas around station D, for example, the average local wave height decreases during these months, and thus a negative coeffienct appears that is unusually large compared to the surrounding frequencies. The seasonal effect of the predominance of the 20-c/s signal is illustrated in figure 8. No peculiar effect appears at these frequencies at the time of minimum occurrence of the 20-c/s signals (May and June).

Comparable results are yielded for all four stations by the following data sets:

1. Occurrences for which the value of wave height above the source was less than 3 feet, and

2. Occurrences for which the value of wave height above the source was less than 3 feet *and* the value at the 200-nautical-mile range was 3 feet. Station A (fig. 9) is typical. The smallest number of points in any of the computations for data set 1 was 149; for data set 2, 107. The first group shows a general decrease for the coefficients compared to the parent sample (fig. 6) for nearly all frequencies with the smallest decrease in the 16-to-25-c/s region.

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* Greatest 1 percent minimum critical value for the four stations is 0.13.

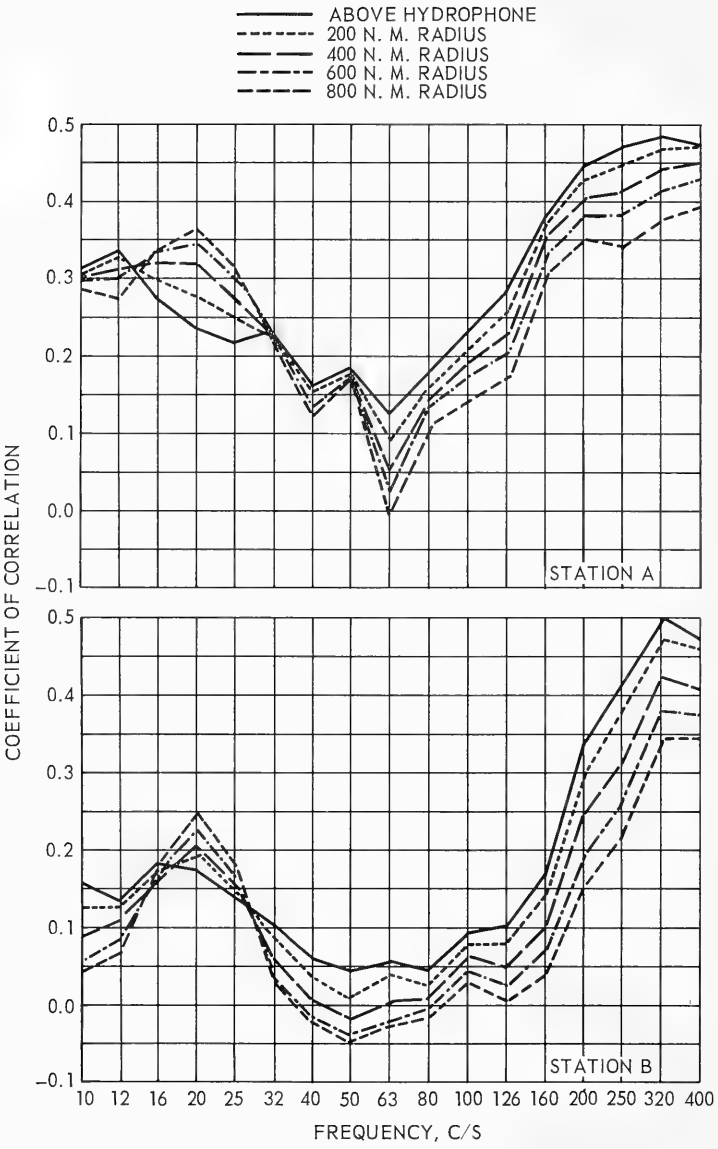

Figure 6. Variation with frequency of coefficient of correlation between sound pressure spectrum level and cumulative maximum wave heights observed at the indicated radial distances for the hours 0600 and 1800 GMT, April through December 1964.

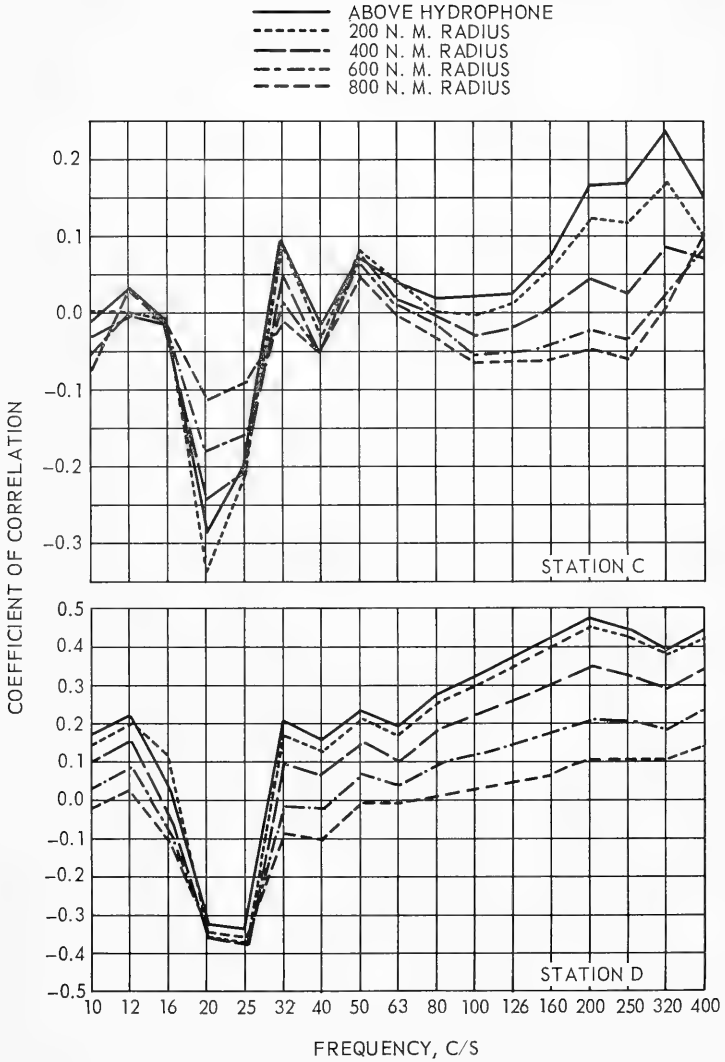

Figure 6. (Continued).

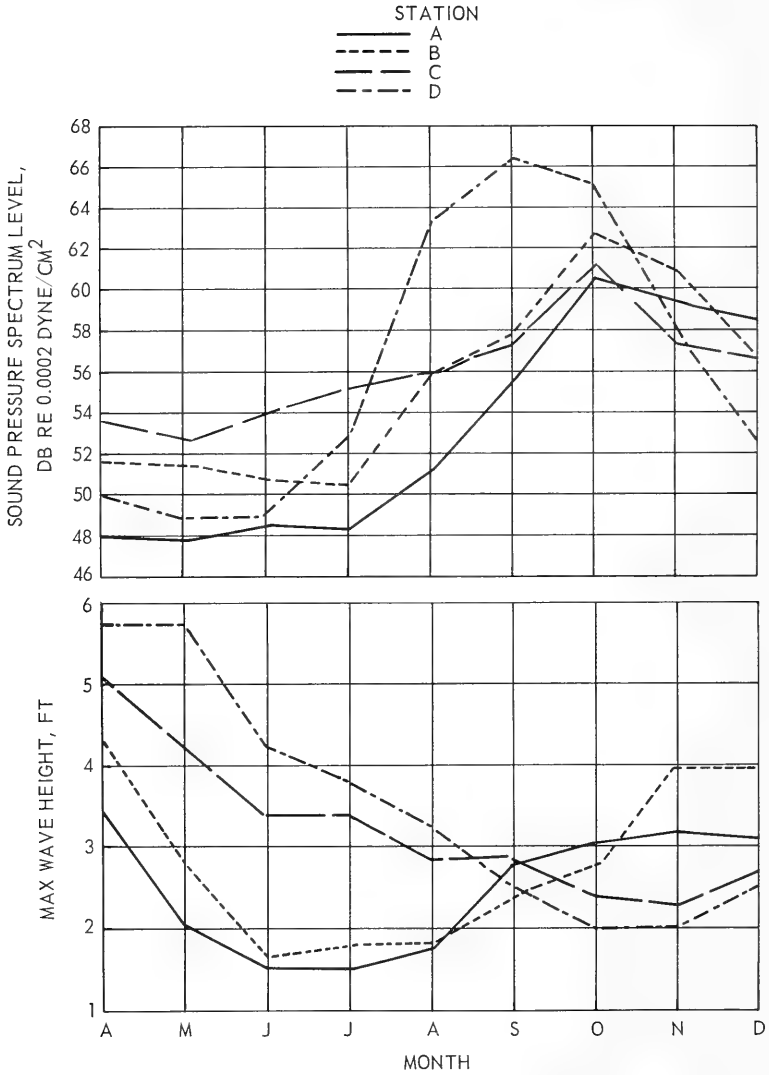

Figure 7. Monthly average sound pressure level at 20–c/s midband frequency, and monthly average local wave height.

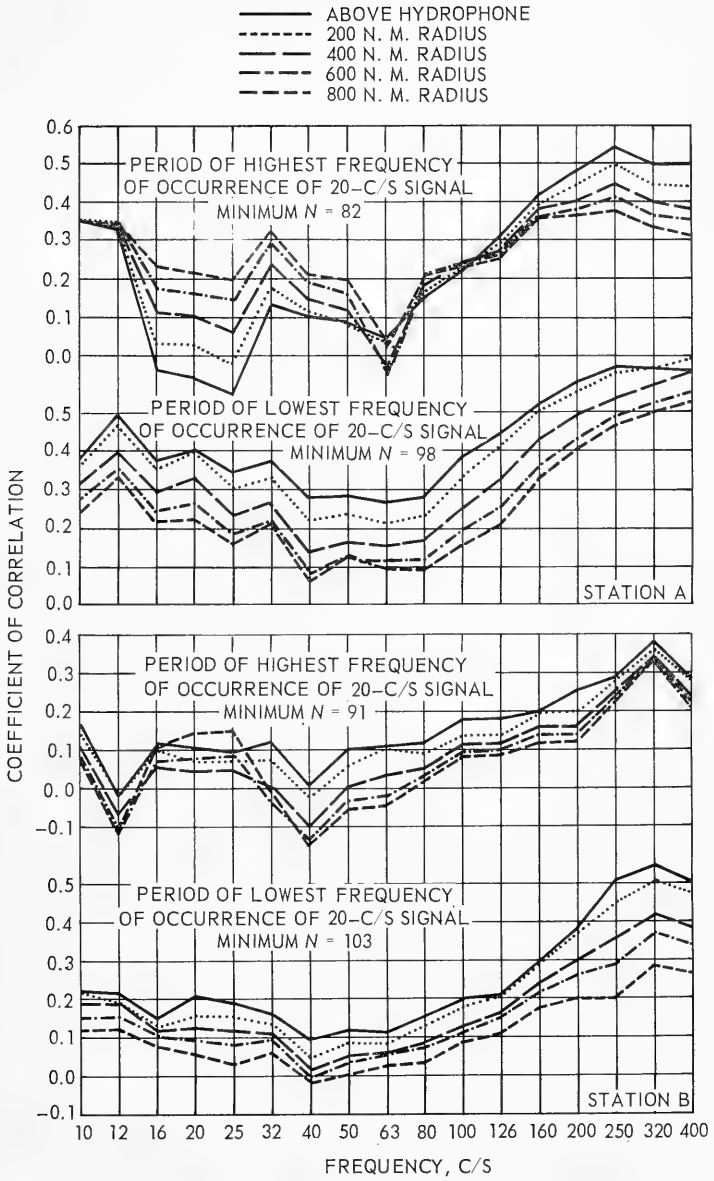

Figure 8. Variation with frequency of coefficient of correlation between sound pressure spectrum level and cumulative maximum wave heights observed at the indicated radial distances.

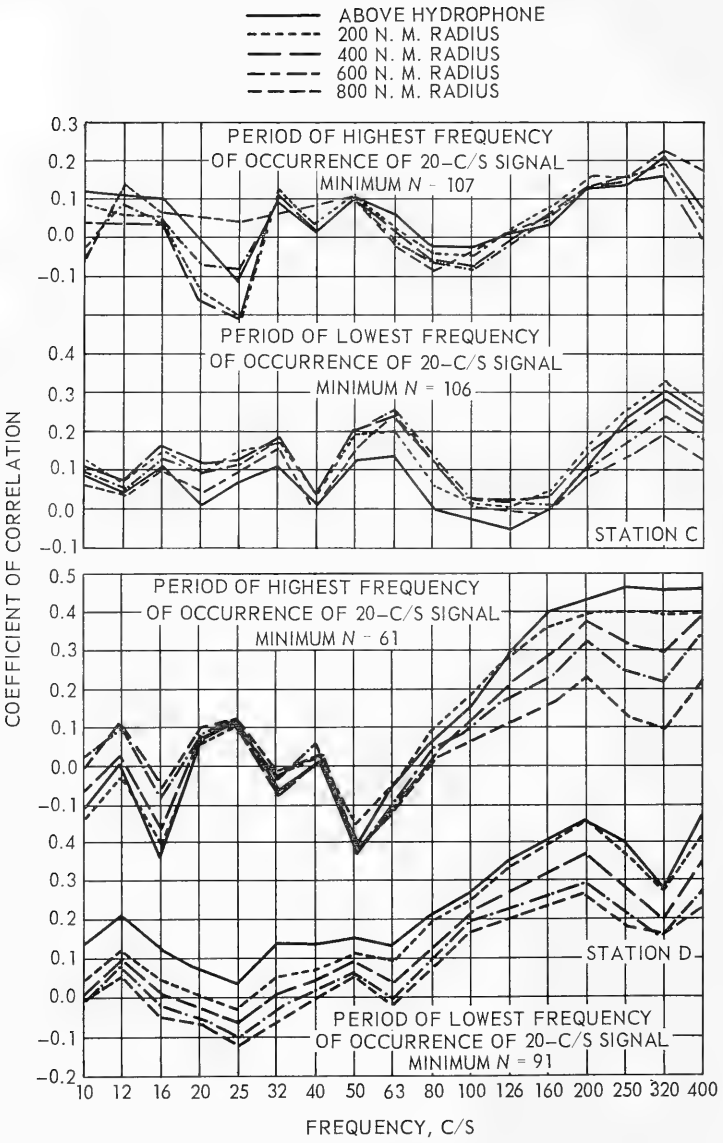

Figure 8. (Continued).

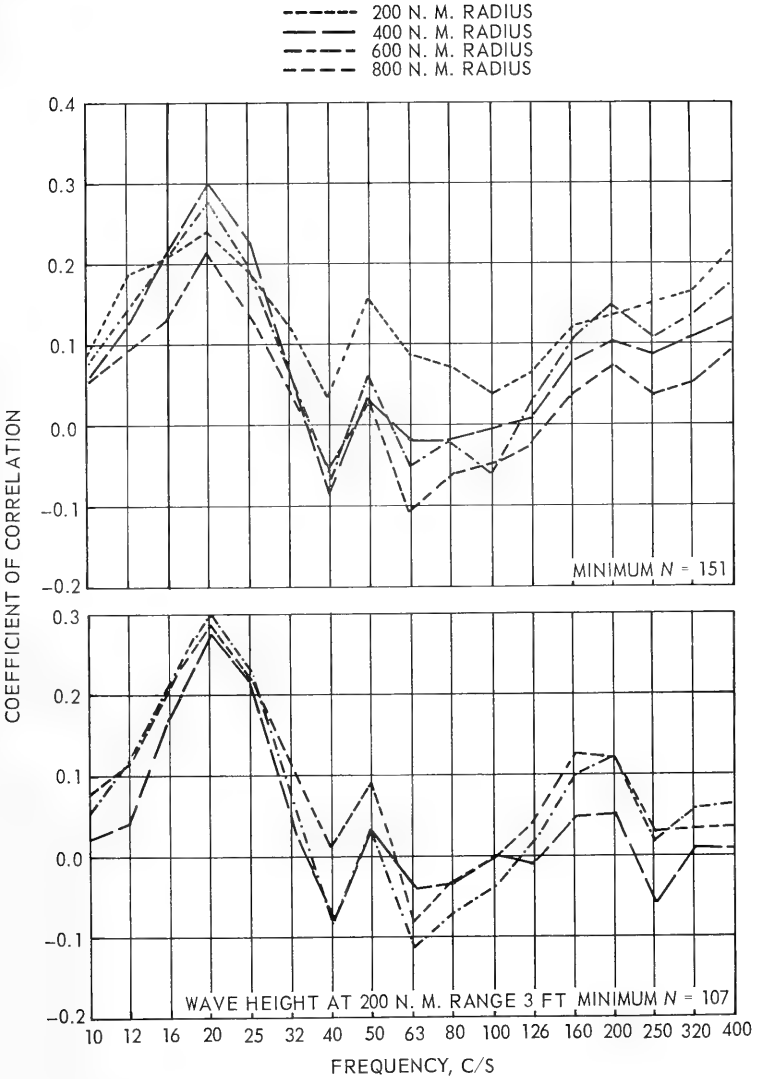

Figure 9. Variation with frequency of coefficient of correlation between sound pressure spectrum level and maximum wave heights observed at the indicated radial distances for periods during which wave height at source was less than 3 feet, April through December 1964.

At the 1-percent level, the critical absolute value of the correlation coefficient is about 0.21. The second group suggests that all frequencies with the exception of 20 c/s are unaffected by fluctuation in sea height at ranges greater than 200 nautical miles (1-percent absolute critical value for the second group is 0.25). Again, the suggested relationship in this narrow frequency grouping is probably merely a coincidental result from the presence of 20-c/s signals, and not the result of distant storm activity.

Although the near-wind effect on noise has been described in the literature, it was desired to use the data from the Navy weather buoy for comparison with ambient-noise levels, and to perform the same correlation computations on the same frequency range as with the wave-height comparisons. There were several advantages in using the buoy data — consistency of location of the anemometer in relation to the surface and station, and accurate wind-speed measurement. The wind data were compared with noise data received from station D. The weather buoy was located about 50 miles from the hydrophone location. The results (fig. 10) show a high noise/wind correlation in the higher frequencies (above 160 c/s) and no correlation for 10 to 16 c/s and 32 to 80 c/s . Minimum critical value at the 1-percent level for the 150 points is about 0.208. Although the number of data points was limited, a sufficient number of points existed to group the data into categories of Beaufort 2 (4 to 6 knots), Beaufort 3 (7 to 10 knots), and Beaufort 4 (11 to 16 knots)[9] (fig. 11). Standard tests (t statistic) on significance of mean-value differences for the Beaufort groupings were run for select frequency bands. Differences in mean levels for the Beaufort groupings for frequencies of 200 c/s or greater were significant at a 1-percent level. In the 20-to-25-c/s region only a few pairs (sound pressure level at 20 c/s for Beaufort 3 compared with Beaufort 2, for example) were significant (5-percent level).

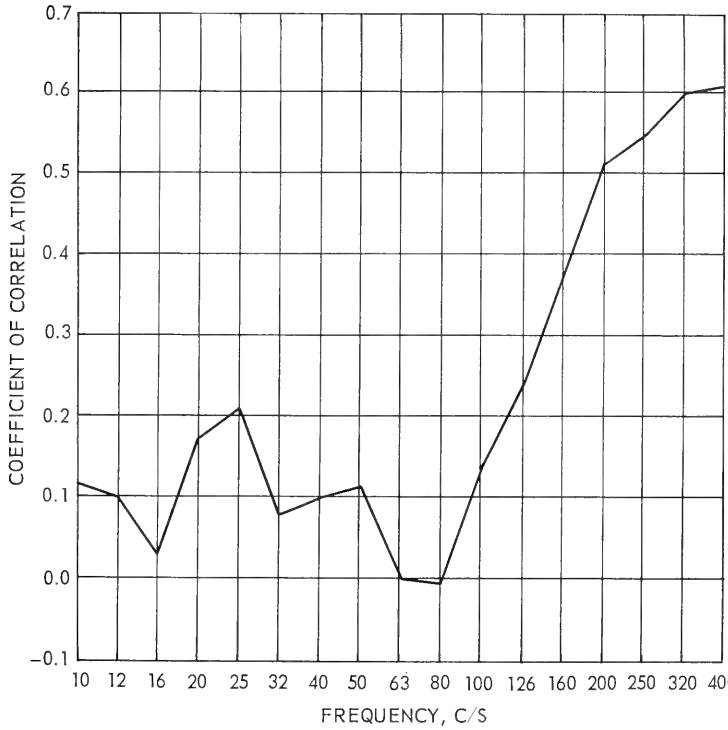

Figure 10. Variation with frequency of coefficient of correlation between sound pressure spectrum level and wind speed measured at Navy weather buoy.

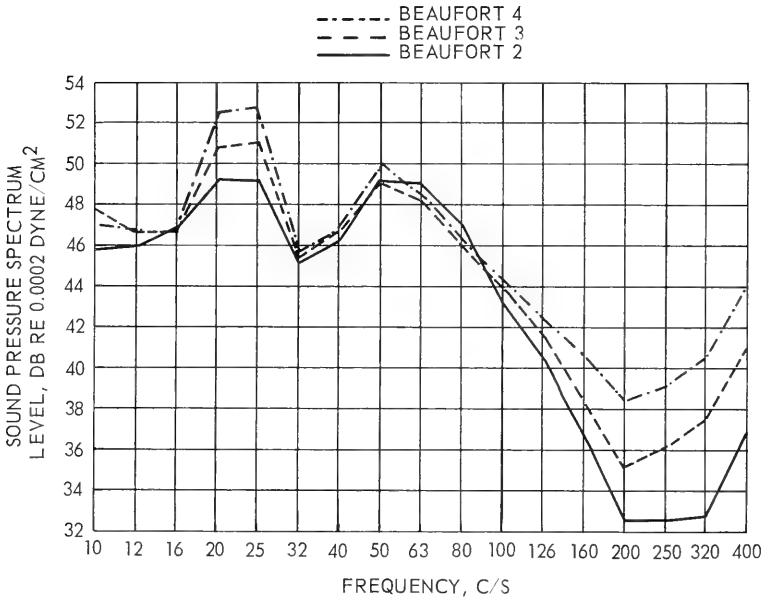

Figure 11. Ambient noise versus frequency at station D, June through August 1965.

CONCLUSIONS

Many of the forms of weather data now available (the data from Fleet Numerical Weather Facility are considered the best in the sense of the overall patterns they describe) do not lend themselves well to this type of study. To use a high coefficient of correlation in a derivation of a regression line prediction model, one must be assured that the accuracy of measurement of the independent variable is significantly greater than that of the dependent variable (ambient noise). Such was not the case with data used in this study. However, even though precise prediction relations cannot be formulated, an indication is provided of the frequency regions in which the noise is affected by wind and wave height at deep-mounted hydrophones in open-ocean locations.

The results do not support the hypothesis of very-long-range noise/storm dependence. They do suggest that both wind speed and local wave activity have a significant effect on underwater ambient noise greater than about 160 c/s, and that local wave activity may have a small effect on low-frequency noise. By using a 30-hour prediction chart, available at Fleet Numerical Weather Facility, one may be able to predict whether the noise will increase or decrease in regions greater than 160 c/s and to provide a gross estimate of the amount of change. The general dip in the correlation coefficient to insignificant values in the midfrequency range (32 to 160 c/s) for most of the stations is probably due to masking by ship and traffic noise.

REFERENCES

1. National Defense Research Committee. Division 6 Report 6.1-NDRC-1848, Survey of Underwater Sound: Report No. 3; Ambient Noise, by V. O. Knudsen and others, 26 September 1944 (PB 31021)

2. Wenz, G. M., "Acoustic Ambient Noise in the Ocean: Spectra and Sources," Acoustical Society of America. Journal, v. 34, p. 1936-1956. December 1962

3. Navy Electronics Laboratory Technical Memorandum 840, Effect of Winds on the Underwater Low Frequency Ambient Noise Recorded at a Location Off the West Coast of the United States, by W. L. Frisch and T. S. Scanlan, 8 September 1965*

4. Fleet Numerical Weather Facility, Monterey, California, Operational Forecasts of Sea and Swell, by W. E. Hubert, (1964)

5. Fleet Numerical Weather Facility, Monterey, California, Numerical Environmental Prediction Progress Report, May 1964

6. Navy Electronics Laboratory Report 938, Third-Octave Digital Analyzer (TODA), by J. V. Schaefer, 16 December 1959

7. Navy Electronics Laboratory Report 1286, Modification of Third-Octave Digital Analyzer (TODA), by R. E. Cruse, 10 May 1965

8. Cummings, W. C. and Thompson, P. O., "20-Hz Signals in the Northeast Pacific," in Third U. S. Navy Symposium on Military Oceanography, CONFIDENTIAL, 1966 (In press)

9. Von Arx, W. S., An Introduction to Physical Oceanography, p. 68, Addison - Wesley Publishing Company, Incorporated, 1962

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Report 1390

SEA NOISE VS NEAR AND DISTANT WAVE HEIGHT AND WIND SPEED, by W. L. Frisch, 24 p., 11 Jul 66.

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1. Sound pressure spectrum level is influenced by wave height and wind speed at both ends of the frequency range considered (10 to 400 c/s); influence is greatest between 160 and 400 c/s.

2. Ambient-noise levels between 32 and 160 c/s are the least influenced by near and distant wave height.

3. For periods during which local wave heights were moderate and uniform, no dependence of ambient-noise level on distant wave-height fluctuation was observed.

1. Ocean Waves - Acoustic Properties
2. Underwater Noise - Analysis

I. Frisch, W. L.

SF 101 03 15, Task 8119
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